REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
3/6/01

3. REPORT TYPE AND DATES COVERED
8/1/97 - 8/31/00 Final

4. TITLE AND SUBTITLE
Globally Distributed Microsystems Design: Proof-of-Concept

5. FUNDING NUMBERS
DAAG55-97-1-0345

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RECEIVED
MAY 10 2001
By

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
37575.1-CI

11. SUPPLEMENTARY NOTES
The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The rapid advances in computing and networking technologies continue to stimulate formations of distributed teams worldwide. The advantages of an effective distributed design environment of tools, databases, and data management include the opportunity for a rapid assembly of a project-specific team of specialists who can immediately contribute towards the goals of the project -- from almost anywhere, at any time.

The DARPA-funded Vela project, named after constellation that forms the sail of Argo Navis (the Argonauts ship), brought together distributed university-based participants from six locations: MIT (Massachusetts Institute of Technology), MSU (Mississippi State Univ.), NCSU (North Carolina State Univ.), Stanford University, UCB (Univ. of California, Berkeley), and UCSC (Univ. of California, Santa Cruz). As conceived initially, the project was to balance two major tasks: a multi-media processor design as a project driver, and a web-based tool set for distributed design and benchmarking as the project infrastructure, with a major deliverable as a proof-of-concept demo in the University Booth during the Design Automation Conference. A total of three such demos were presented during 1998-2000, and a web-based archive of 26 peer-reviewed publications, data sets, software prototypes, and demo presentations are now accessible from http://www.cbl.ncsu.edu/vela and http://www.cbl.ncsu.edu/OpenProjects/.

14. SUBJECT TERMS
Collaborative Computing Distribution Design Environment

15. NUMBER OF PAGES
12

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Final Report to DARPA/ARO

under DAAG55-97-1-0345

Project Duration: August 1, 1997 – August 31, 2000

Globally Distributed Microsystems Design: Proof-of-Concept

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Report Summary. The rapid advances in computing and networking technologies continue to stimulate formations of distributed teams worldwide. The same advances also provide challenges and opportunities to develop new models of collaboration and collaborative technologies. Examples of generic collaborative 'groupware' technologies such as e-mail, video conferencing, shared access to databases of documents and images, shared white boards, are for most part readily available and well-supported commercially. On the other hand, technologies that would streamline and support *distributed* electronic design automation and engineering workflows are for the most part proprietary or under development. The advantages of an effective distributed design environment of tools, databases, and data management include the opportunity for a rapid assembly of a project-specific team of specialists who can immediately contribute towards the goals of the project – from almost anywhere, at any time.

The DARPA-funded Vela project, named after constellation that forms the sail of Argo Navis (the Argonauts ship), brought together distributed university-based participants from six locations: MIT (Massachusetts Institute of Technology), MSU (Mississippi State Univ.), NCSU (North Carolina State Univ.), Stanford University, UCB (Univ. of California, Berkeley), and UCSC (Univ. of California, Santa Cruz). As conceived initially, the project was to balance two major tasks: a multi-media processor design as a project driver, and a web-based tool set for distributed design and benchmarking as the project infrastructure, with a major deliverable as a proof-of-concept demo in the University Booth during the Design Automation Conference. A total of three such demos were presented during 1998-2000, and a web-based archive of 26 peer-reviewed publications, data sets, software prototypes, and demo presentations are now accessible from http://www.cbl.ncsu.edu/vela and http://www.cbl.ncsu.edu/OpenProjects/.

Report Organization. This report is organized into following sections:

- project motivation and background
- project deliverables
- representative project demo examples
- list of project-related publications (posted under http://www.cbl.ncsu.edu/vela/publications)

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Background and Motivation

The rapid advances in computing and networking technologies continue to stimulate formations of distributed teams worldwide. The same advances also provide challenges and opportunities to develop new models of collaboration and collaborative technologies. Examples of generic collaborative 'groupware' technologies such as e-mail, video conferencing, shared access to databases of documents and images, shared white boards, are for most part readily available and well-supported commercially. On the other hand, technologies that would streamline and support *distributed* electronic design automation and engineering workflows are for the most part proprietary or under development. The advantages of an effective distributed design environment of tools, databases, and data management include the opportunity for a rapid assembly of a project-specific team of specialists who can immediately contribute towards the goals of the project – from almost anywhere, at any time.

The DARPA-funded Vela project, named after constellation that forms the sail of Argo Navis (the Argonauts ship), initially brought together distributed university-based participants from six locations: MIT (Massachusetts Institute of Technology), MSU (Mississippi State Univ.), NCSU (North Carolina State Univ.), Stanford University, UCB (Univ. of California, Berkeley), and UCSC (Univ. of California, Santa Cruz). As conceived initially, the project was to balance two major tasks: a multi-media processor design as a project driver, and a web-based tool set for distributed design and benchmarking as the project infrastructure.

However, the reduction and the staggered schedule of funding reduced the level of project participation to five co-PIs by June of 1999, and three co-PIs by June 2000. With remaining participants, there was increased emphasis on the infrastructure to formalize the collaborative design process itself. With the design-driver no longer an option, emphasis shifted to expanding and testing novel the web-based client/server architectures that can intrinsically support distributed collaborative environments and processes. Additional milestones were added to the project after rebudgeting: a joint paper with MIT, MSU, and NCSU about the demo at DAC'1999, and an expanded demo with MSU participants during DAC'2000.

Deliverables and Accomplishments

The main thrust and the deliverable of this project was to demonstrate how effectively can a distributed team of faculty and student organize their environment to (1) create a prototype design, and (2) conduct a series of distributed experiment to evaluate the performance of a CAD tool or an algorithm.

Originally, there we to be two sets of demos in the University Booth of the Design Automation Conference (DAC): the introductory one in June 1998 and the final one in June 1999. For reasons, explained in the earlier section. the schedule was extended after re-budgeting and subsequently, there were three sets of demos as follows:

Demos at DAC 1998:
The 1998 demos brought together project participants from Stanford U., UC Berkeley, UC Santa Cruz, MSU, MIT and NCSU. This was a 'getting acquainted'demo since a few of participants received funding just a few months before.

Demos at DAC 1999:
The 1999 demos brought together project participants from Stanford U., UC Berkeley, MSU, MIT and NCSU. However, only MSU, MIT and NCSU would reach the level of cordination such that their tools could be integrated into a representative design environment on the Web. Since not all the funding was spent, project was rebudgeted for another demo at DAC 2000 by MSU and NCSU.

Demos at DAC 2000:
The 2000 demos extended and formalized the distributed collaboration environment first demonstrated during DAC'1999.

Accomplishments. Coordinating a collaborative activity among distributed academic participants is no small task. An objective measure to evaluate accomplishments of this project in particular may not be readily available. However, the project did produce:

- a number of peer-reviewed publications (a total of 12 + 16 are itemized in two distinctive categories in the last section of this report);

- a web-based archive of all listed publications, data sets, software prototypes, and demo presentations – to serve as a resource to the design automation community and others (http://www.cbl.ncsu.edu/vela and http://www.cbl.ncsu.edu/OpenProjects/).

Representative Project Demo Examples

The main thrust and the deliverable of this project was to demonstrate how effectively can a distributed team of faculty and student organize their environment to (1) create a prototype design, and (2) conduct a series of distributed experiment to evaluate the performance of a CAD tool or an algorithm.

Three sets of demos were organized during this project in the University Booth of the Design Automation Conference (DAC) and presented in June 1998, June 1999, and June 2000. Each year reflects the experience gained from the previous year. Details about each demo, copies of slides, reprints of related publications are provided in the next section. In this section, we reproduce some of the actual presentation material in Figures 1–4 to illustrate the organization and highlights of these demos.

Demos at DAC 1998:

The 1998 demos brought together the project participants a few months after the start of the project. It server tow purposes: (1) to demonstrate one's team capabilities attained in the past in the context of how they may related to the tasks in the current project, (2) to outline the shared undestanding of the tasks as they are to be performed to meet the goals of 1999 demo. The summary of project objectives and project milestones is shown in Figure 1. Notably, at this demo, 6 teams participated: UC Berkeley, Stanford U., UC Santa Cruz, Missisipi State U. (MSU), MIT, and NC State U. (NCSU).

Demos at DAC 1999:

The 1999 demos fullfilled some but not all of the objectives of this project. Notably, participants in the design driver part of the project could not participate at the level expected and resigned from the project. However, the work on the web-based tools and infrastructure compensated by not only demonstrating stand-alone web-based design tool capabilities but also a user-configurable virtual design environment. Specifically, as shown in Figure 2, participants from MIT, MSU, and NCSU succeeded to create and demonstrate this environment.

In the first phase of the demo, `collabtop@mit` and `javacadd@msu` are tested as stand-alone tools residing on servers at MIT nad MSU. The OmniDesk/Flow client at NCSU allows a distributed design team (from MIT, MSU, NCSU) to collaborate by creating a user-configurable virtual design environment. All tools and data now appear to reside in this environment. User can now configure a *sequence* of design tasks to be executed and negotiate permissions to access/change data that is protected by other designers. Design data owned by a designer at MIT/MSU/NCSU cannot be changed without his/her permission.

Demos at DAC 2000:

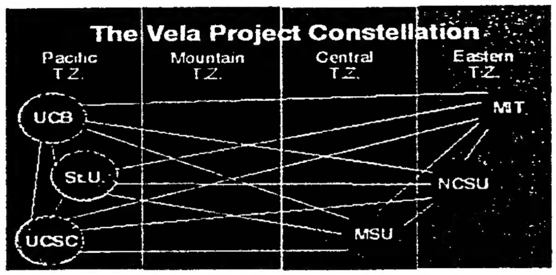
The 2000 demos extended and formalized the distributed collaboration environment first demonstrated during DAC'1999. This last phase of the project was easier to coordinate since there were only two participants: MSU and NCSU. Highlights of the demos that took place are shown in Figures 3 and 4. We extended the user-configurable environment to support multiple sets of design flows and engaged a a faculty member and a team of senior/graduate students in a class project at NCSU to create to representative environments using the OmniFlow client: *OpenDesign* and *OpenExperiment* environment. The OpenDesign environment interconnects a number of distributed tools from NCSU and MSU, provides ready R/W access to data directories, also accessible with the web-browser. The OpenExperiment sets up and experimental design test-bed prototype into which users can 'plug' algorithms and data for comparative evaluation, also posted on the Web.

Demos were conducted in real time on two workstations connected to the Internet, accessing servers at MSU and NCSU.

Much more details and full access to 26 publications related to this project are given in the next section.

A University Booth demo at DAC'98, June. 15-17, 1998, San Francisco, CA

Globally Distributed Microsystem Design: Proof-of-Concept



http://www.cbl.ncsu.edu/vela/

Project Objectives

1. Align system designers, library and tool providers, and system integrators in a unique proof-of-principle project driven by a complex multimedia processor design, to be taken through several design stages: from conception, through exploration of architectural alternatives,
   simulation, verification, performance and power analysis, floorplanning, and synthesis.

2. Demonstrate, using and extending the current Internet-based technologies, the feasibility of a large-scale distributed and collaborative design effort of a complex microelectronic system:
   with participants, servers, tools, and libraries distributed across the USA.

3. Develop new techniques, evaluate challenges, identify opportunities and needs for the next generation of
   distributed and collaborative design technologies.
   keeping pace with the rapid advances in semiconductor technologies and the emergence of Internet-II.

Project Milestones

DAC'98 Demo:

(1) focus on **analysis** and tentative approaches to working with distributed participants, servers, tools, and data;

(2) demonstrate **work-in-progress** ranging from innovative web-based point tools. encapsulation of commercial tools for remote execution without relying on user-accounts, collaborative workflows that invoke a number of distributed tools and execution sequences, to the definition, abstractions, and analysis of the design driver chip.

DAC'99 Demo:

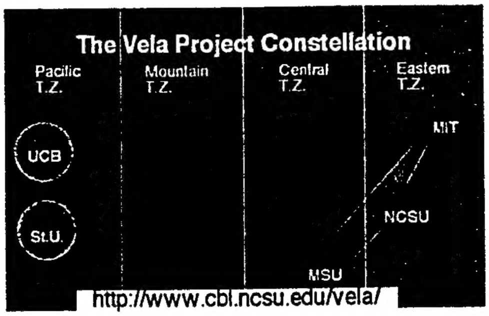
(1) focus on **integration architectures and testing**, by all participants, of distributed servers, tools, and data into well-defined executable and collaborative design workflows -- while **supporting the design driver**;

(2) demonstrate feasibility and limitations of migrating most if not all access of tools, data, and design workflows to **platform-independent interfaces**, i.e. accomplish most if not all design transactions through the nominal web-browser.

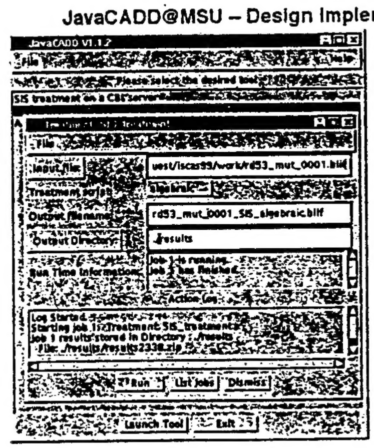
Figure 1: Introduction to the 'getting acquainted' demos at DAC'1998.

A University Booth demo at DAC'99, June 21-23, 1999, New Orleans, LA

Vela Project
on Collaborative Distributed Design:
New Client/Server Implementations

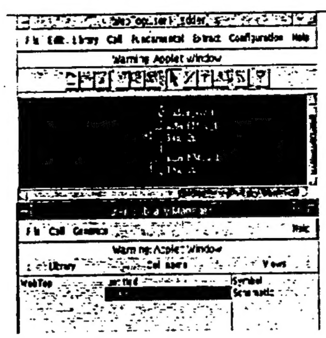


JavaCADD@MSU – Design Implementation Server



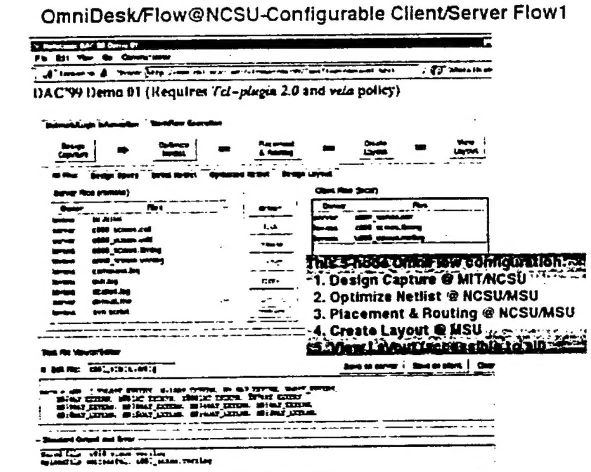
1. get a netlist/directory via URL, ftp, ssh, telnet, ...
2. submit each netlist to a RMI-invoked toolserver (any university or commercial toolsets) via JavaCADD client
3. save the resulting files returned by JavaCADD client in a local directory.

CollabTop@MIT – Collaborative Design Capture Server



1. enter and edit schematics with two remote participants
2. extract a netlist for simulation and verification
3. extract a netlist and save under a protected URL on the web, to be optimized and a layout created by the remote project participants.

OmniDesk/Flow@NCSU-Configurable Client/Server Flow1



In the first phase of the demo, collabtop@mit and javacadd@msu are tested as stand-alone tools residing on servers at MIT and MSU.

The OmniDesk/Flow client at NCSU allows a distributed design team (from MIT, MSU, NCSU) to collaborate by creating a user-configurable virtual design environment. All tools and data now appear to reside in this environment. User can now configure a *sequence* of design tasks to be executed and negotiate permissions to access/change data that is protected by other designers. Design data owned by a designer at MIT/MSU/NCSU cannot be changed without his permission.

Figure 2: Introducing screenshots of to individual tools and tool flow demos at DAC'1999.

University Booth Demo at DAC'2000, June 5-6, 2000

OpenDesign & OpenExperiment:

User-Configurable Collaborative Project Environments on the Internet

NCSU Participants:
Dr. F. Brglez, H. Lavana. D. Ghosh,
B.Allen, R. Casstevens, J. Harlow III,
R. Kurve, S. Page, M. Stallmann

MSU Participants:
Dr. Robert Reese, Suwei Chen

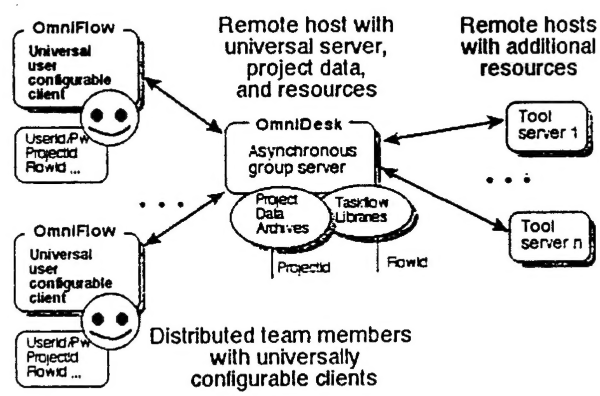
Collaborative Demo Schedule (on two workstations)

Monday 11:00--12:00
Tuesday 11:00--12:00
Wednesday .. 11:00--12:00

Typical OpenDesign scenarios:
(1) Web access to a commercial layout tool at MSU
(con: one netlist entry per web form)
(2) Download a generic taskflow (OmniFlow client)
(3) Configure OmniFlow to access tools at MSU
(4) Execute OmniFlow for a chain of tasks
(pro: a generic GUI configured for multiple netlist, chain-of-tasks execution)
(5) Post the OmniFlow results on the Web

Typical OpenExperiment scenarios:
(1) Download a generic taskflow (OmniFlow client)
(2) Configure OmniFlow for equiv. class generation
- create and post equiv. circuit class on the Web
(4) Configure OmniFlow for an experiment
- A executes algorithm A1 on station 1.
- B executes algorithm B1 on station 2.
(5) Configure OmniFlow to evaluate both experiments
- generate summary for peer review
- post results and summary on the Web.

OmniFlow/OmniDesk C/S Architecture



- Neither the client nor the server are project-specific.
- **OmniDesk** is installed on a unix/linux host.
- **OmniFlow** is downloadable as a cross-plaform executable
- ***User-defined*** configuration file and taskflow library creates the environment invoked by OmniFlow.

Figure 3: Introduction to OpenDesign and OpenExperiment demos at DAC'2000.

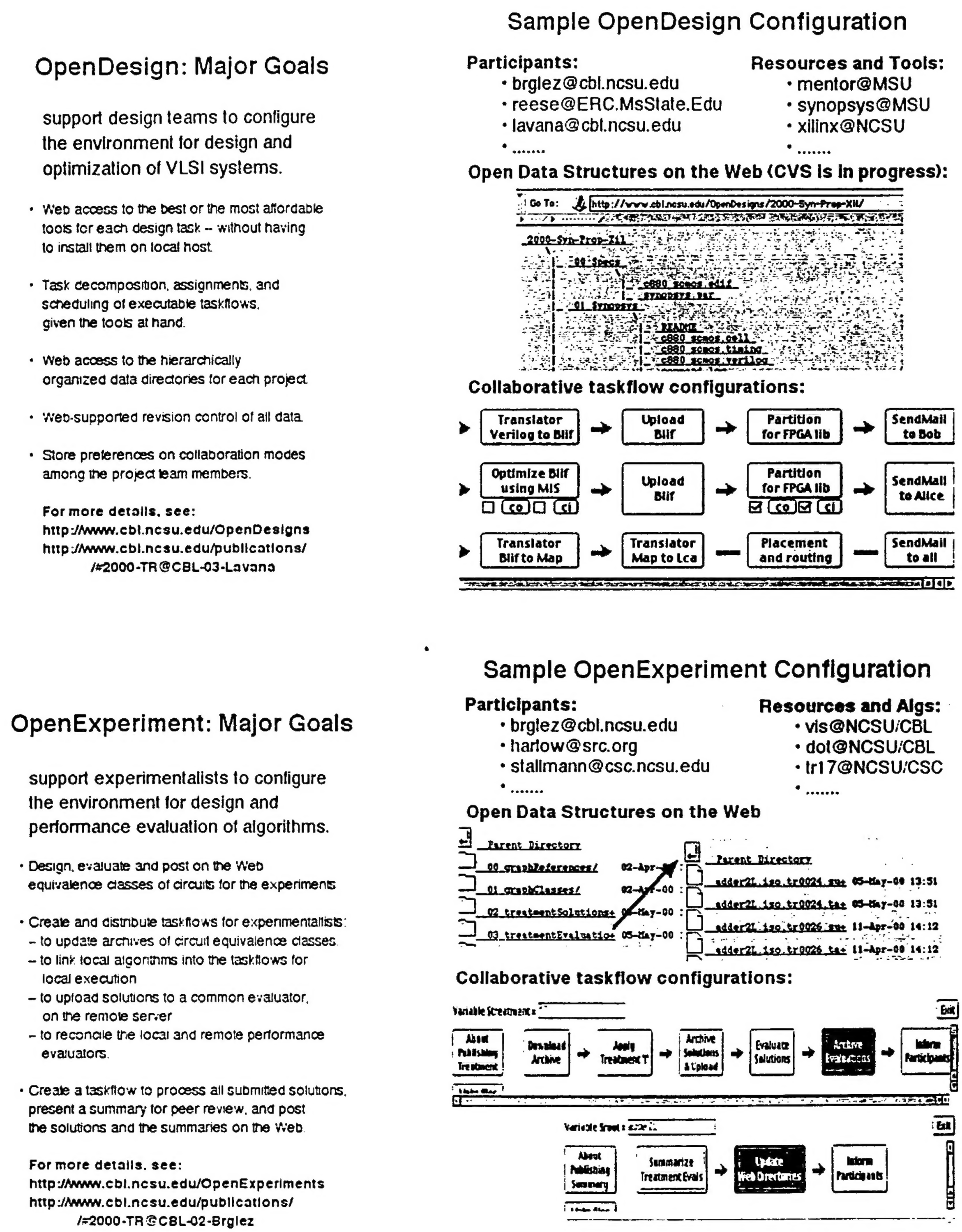


Figure 4: Screenshots of OpenDesign and OpenExperiment demos at DAC'2000.

Lists of Project-Related Publications

This section compiles comprehensive lists of project-related publications. The collaborative theme of this project also captured interest of participants not funded by the project: these include faculty, graduate and senior-level students at NCSU, as well as faculty members and graduate students from Europe and other locations in USA. Dr. Franc Brglez provided direction to teams of graduate and senior-level students in special topics project-related courses at NCSU and organized two sessions at the International Symposium on Circuits and Systems (ISCAS 1999) on the topic of "Changing the Benchmarking Paradigm in CAD and the Role of WWW " with 10 participants publishing and presenting 8 papers in two sessions.

To bring out the diversity of participants *and* themes in this collaborative project, we list the related publications under three categories:

- Collaborative demos and status reports by project participants;
- Collaborative publications by participants funded by this project.
- Collaborative publications with participants not all funded by this project.

As conceived initially, the project was to balance two major tasks: a multi-media processor design as a project driver, and a web-based tool set for distributed design and benchmarking as the project infrastructure. The momentum of the project was expected to peak in time for the 1999 DAC in June. However, the reduction and the staggered schedule of funding reduced the level of project participation to five co-PIs by June of 1999, and three co-PIs by June 2000. With remaining participants, there was increased emphasis on the infrastructure to formalize the collaborative design process itself. With the design-driver no longer an option, emphasis shifted to expanding and testing novel the web-based client/server architectures that can intrinsically support distributed collaborative environments and processes. Additional milestones were added to the project after rebudgeting: a joint paper with MIT, MSU, and NCSU about the demo at DAC'1999, and an expanded demo with MSU participants during DAC'2000. Notably, the phase of the NCSU project continued beyond the funding completion in August 2000, and culminated in a ground-breaking PhD thesis in December 2000 under the direction of Dr. Franc Brglez. The final experiments in this thesis also re-engaged the collaborative design services from one of the original particpants in this project, Dr. R. B. Reeves from MSU. As most of this project's activity in the past, the submission on this most recent phase of the thesis research has been accepted for publication (at DAC'2001).

To access publications in this report, follow the hyperlinks from http://www.cbl.ncsu.edu/vela/all-publications.html.

Project Status Reports and Demos:

Notably, [1] and [2] were written by reporters in the initial phase of the project (with the information provided by Dr. Franc Brglez). The final project demos are described in [9] and [10].

1. R. Goering. Vela project could chart new course for engineering on the Net – Web-based design hoists new sail. In *EE Times*, June 1997. Also available at `http://www.cbl.ncsu.edu/publications_others/1997-DAC-EE_Times-Goering/`.
2. L. Geppert. IC Design on the World Wide Web. *IEEE Spectrum*, pages 45–50, June 1998. Includes a special section "Sailing on the Internet" about the Vela Project, pp. 45–47. See `http://www.spectrum.ieee.org/` for details.
3. F. Brglez (Editor). Vela Project – Globally Distributed Microsystem Design – Proof of Concept: Demo Summaries of the 1998 DAC Exhibition in the University Booth. Technical Report Draft, June 1998. Also available at `http://www.cbl.ncsu.edu/vela/1998-VelaDemoDraft-Brglez.pdf`.
4. F. Brglez (Editor). Vela Project - Globally Distributed Microsystem Design - Proof of Concept: Poster-foils for the 1998 DAC Exhibition in the University Booth. , June 1998. Posted under `http://cbl.ncsu.edu/publications_misc/1998--Talk-DACdemo/`.
5. T. Meng. Vela Project Report, February 1999. Posted under `http://www.cbl.ncsu.edu/vela/-1999-VelaFinal-Meng.html`.
6. G. De Micheli. Vela Project Report: A Network Communication Module, March 1999. Posted under `http://www.cbl.ncsu.edu/vela/1999-VelaFinal-DeMicheli.html`.

7. R. Newton M. Spiller. Data Models and Design Data Management, July 1999. Posted under http://www.cbl.ncsu.edu/vela/1999-VelaFinal-Spiller.html ... For an update, may also check http://www-cad.eecs.berkeley.edu/~mds/.

8. F. Brglez (Editor). Vela Project on Collaborative Distributed Design: New Client/Server Implementation. In *EE Times* (Special DAC'99 supplement on "web-based engineering") , June 21 2001. June 1999. Available at http://www.cbl.ncsu.edu/vela/1999-EETimes-vela.pdf For slides of the 1999 DAC Exhibition in the University Booth, see http://www.cbl.ncsu.edu/vela/-1999--Talk-DAC-demo.pdf.

9. R. B. Reese. ECAD Services for WWW in the Vela Project, August 2000. Posted under http://www.cbl.ncsu.edu/vela/1999-VelaFinal-Reese.pdf.

10. F. Brglez. OpenProjects Home Page, with links to DAC'2000 Vela Project Demos and Software, including OpenExperiment, OpenDesign, and JavaCADD Services, June 2000. See http://www.cbl.ncsu.edu/OpenProjects/.

Publications with participants funded by this project:
(distributed computing infrastructure, distributed experimental design and evaluation of CAD algorithms)

1. F. Brglez. Design of Experiments to Evaluate CAD Algorithms: Which Improvements Are Due to Improved Heuristic and Which Are Merely Due to Chance? Technical Report 1998-TR@CBL-04-Brglez, CBL, CS Dept., NCSU, Box 7550, Raleigh, NC 27695, April 1998. Also available at http://www.cbl.ncsu.edu/publications/#1998-TR@CBL-04-Brglez.

2. D. Linder, R. Reese, J. Robinson, and S. Russ. JavaCADD: A Java-based Server and GUI for Providing Distributed ECAD Services. Technical Report MSSU-COE-ERC-98-07, Microsystems Prototyping Laboratory, MSU/NSF Engineering Research Center, April 1998. Also available at http://WWW.ERC.MsState.Edu/mpl/publications/papers/javacadd/JCaddTR.pdf.

3. N. Kapur. Cell Placement and Minimization of Crossing Numbers. Master's thesis, Electrical and Computer Engineering, North Carolina State University, Raleigh, N.C., May 1998. Also available at http://www.cbl.ncsu.edu/publications/#1998-Thesis-MS-Kapur.

4. H. Lavana, F. Brglez, and R. Reese. User-Configurable Experimental Design Flows on the Web: The ISCAS'99 Experiments. In *IEEE 1999 International Symposium on Circuits and Systems – ISCAS'99*, May 1999. A reprint also accessible from http://www.cbl.ncsu.edu/publications/-#1999-ISCAS-Lavana.

5. D. Ghosh and F. Brglez. Equivalence classes of circuit mutants for experimental design. In *Proceedings, Intl. Symp. Circuits and Systems (ISCAS)*, May–June 1999. Also available at http://www.cbl.ncsu.edu/publications/#1999-ISCAS-Ghosh.

6. G. Konduri and A. Chandrakasan. A Framework for Collaborative and Distributed Web-Based Design. In *Proceedings of the 36th Design Automation Conference*, June 1999. Posted under http://www.sigda.acm.org/Archives/ProceedingArchives/Dac/Dac99/.

7. H. Lavana and F. Brglez. CollabWiseTk: A Toolkit for Rendering Stand-alone Applications Collaborative. In *Seventh Annual Tcl/Tk Conference*. USENIX, February 2000. Also available at http://www.cbl.ncsu.edu/publications/#2000-TclTk-Lavana.

8. F. Brglez and H. Lavana. Taskflow-Oriented Programming: A Paradigm for Distributed Collaborative Computing. In *12-th IASTED International Conference on Parallel and Distributed Computing, Collaborative Technologies Symposium*. ACTA Press, November 2000. Also available at http://www.cbl.ncsu.edu/publications/2000-CTS-Brglez.

9. H. Lavana, F. Brglez, R. Reese, G. Konduri, and A Chandrakasan. OpenDesign: An Open User-Configurable Project Environment for Collaborative Design and Execution on the Internet. IEEE Intl. Conference on Computer Design, 2000. Also available at http://www.cbl.ncsu.edu/publications/-#2000-ICCD-Lavana.

10. D. Ghosh. *Generation of Tightly Controlled Equivalence Classes for Experimental Design of Heuristics for Graph-Based NP-hard Problems.* PhD thesis, Electrical and Computer Engineering, North Carolina State University, Raleigh, N.C., May 2000. Also available at `http://www.cbl.ncsu.edu/-publications/#2000-Thesis-PhD-Ghosh`.
11. H. Lavana. *A Universally Configurable Architecture for Taskflow-Oriented Design of a Distributed Collaborative Computing Environment.* PhD thesis, Electrical and Computer Engineering, North Carolina State University, Raleigh, N.C., December 2000. Also available at `http://www.cbl.ncsu.edu/-publications/#2000-Thesis-PhD-Lavana`.
12. F. Brglez and H. Lavana. A Universal Client for Distributed Networked Design and Computing. In *Proceedings of the 38th Design Automation Conference*, June 2001. Also available at `http://www.cbl.ncsu.edu/publications/#2001-DAC-Brglez`.

Publications with participants *not all funded* by this project:

(distributed experimental design and evaluation of CAD algorithms, distributed computing infrastructure) Citation [8] points to the home page of 8 papers in the two special sessions at ISCAS'99, the paper [13] summarizes the experience of participants in graduate project course on *Frontiers of Collaborative Computing*, the paper [14] summarizes the experience of senior/graduate students and two faculty members in a project course on prototyping an infrastructure for distributed experimental design and performance evalution of algorithms. Some of the examples developed in [13] were used in the demo at DAC'1999, some of the examples developed in [14] were used in the demo at DAC'2000.

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